TAPPING Transaction Costs to Forecast Acquisition COST BREACHES

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This article uses transaction costs to predict the probability of incurring a cost breach in a major defense acquisition program (MDAP). As transaction costs are not explicitly measured for MDAPs, the authors use estimates of systems engineering and program management (SE/PM) costs as a share of overall program costs as a proxy for transaction costs. Using survival analysis, a new approach to predicting cost breaches, they also found that an increased share of SE/PM costs in initial program estimates can help predict future cost breaches.

KEYWORDS: systems engineering, program management, survival analysis

lead image by Diane Fleischer

Controlling cost growth for a major defense acquisition program (MDAP) has been problematic in the Department of Defense (DoD) for many years. A 2007 RAND study of cost growth in DoD weapon systems determined that the cost of the 46 programs studied was more than 1.46 times the cost estimate for Milestone B (program initiation) (Younossi et al., 2007). According to the Government Accountability Office, active MDAPs in Fiscal Year (FY) 2011 collectively experienced a cost growth of $74.4 billion (Sullivan, 2011).

The Selected Acquisition Report (SAR) was introduced in 1967 to provide DoD and the Congress a summary of each MDAP's ability to meet cost, performance, and schedule objectives agreed upon by the program manager and defense acquisition executive. Program managers were now required to provide a brief explanation in the SAR of how and why any cost breaches occurred.

Based on evidence that this was insufficient to control cost growth, in 1982 Senator Samuel Nunn and Congressman David McCurdy introduced the Nunn-McCurdy Act (1983) to hold DoD accountable to Congress for management of program costs. The Nunn-McCurdy Act became law with the FY 1983 Department of Defense Authorization Act, establishing congressional oversight for MDAPs that exceed established cost thresholds. The Nunn-McCurdy Act has been statutorily amended a number of times over the years. One of the most significant changes to the reporting requirements occurred in the FY 2006 National Defense Authorization Act (Pub. L. 109-163), when Congress added the original baseline estimate as a threshold against which to measure cost growth (National Defense, 2006). The new standard prevents DoD from avoiding a Nunn-McCurdy breach by simply rebaselining a program.

Clearly, the ability to anticipate cost overruns before breaches occur would be extremely valuable to program managers and policy makers. However, the conventional focus on MDAP production costs potentially misses a critical clue. Angelis, Dillard, Franck, and Melese (2008) hypothesize that the higher the ratio of another key set of costs, *transaction costs* (costs associated with "source selection,... contract negotiation and management, performance measuring and monitoring, and dispute resolutions") relative to *production costs*, the greater the likelihood of schedule and cost overruns.

Higher transaction costs are typically experienced in programs that involve greater asset specificity, complexity, and imperfect and asymmetric information—in other words, programs that are at greater risk (Franck & Melese, 2008). Proxy measures first suggested by Angelis et al. (2008) that can be used to capture many of these costs include systems engineering and program management (SE/PM) costs regularly reported by MDAP contractors. It seems reasonable to assume that combined SE/PM costs will be a higher share of total overall estimated costs (production + transaction costs, as predicted at the Milestone B decision point). Program managers, therefore, could reasonably anticipate higher costs in coping with more complex and riskier MDAP projects. Unclear is whether or not these costs are explicitly considered in program cost estimates or simply reflected in the size of SE/PM staff assigned to more complex or high-risk programs.

Background

Many studies (e.g., Bolten, Leonard, Arena, Younossi, & Sollinger, 2008) have examined cost growth in DoD programs, yet little research has been done on the relationship between transaction costs and cost overruns as suggested by Angelis et al. in 2008. A 2006 RAND study established that MDAP SE/PM costs vary between programs depending on the program type (Stem, Boito, & Younossi, 2006), and Angelis et al. (2008) suggested using the SE/PM cost as a proxy for transaction costs to examine the relationship between transaction costs and cost overruns.

In general, a program has two types of costs: production costs and transaction costs. Production costs are usually captured in the Work Breakdown Structure (WBS), but transaction costs may not be adequately captured in the WBS. Because traditional cost estimates are based on the production costs found in the WBS, they do not explicitly include transaction costs

(Angelis et al., 2008). Although they are not often captured in the accounting records, the time and effort associated with complex and risky MDAP transactions represent real costs to the organization.

In previous research, Angelis et al. (2008) examined how transaction costs might be captured in the cost estimates of DoD acquisition programs. Angelis et al. identified a number of issues with DoD program management cost data reported for major weapon systems and found that they are not well suited for developing a cost model that includes transaction cost variables. As an alternate approach, they explored using contractor Program Management data from cost data summary reports (DD Form 1921) and suggested using the SE/PM category as a proxy for transaction costs. The DoD (2011a) defines systems engineering as "the technical and management efforts of directing and controlling a totally integrated engineering effort of a system or program." Program management is defined as "the business and administrative planning, organizing, directing, coordinating, controlling, and approval actions designated to accomplish overall program objectives, which are not associated with specific hardware elements and are not included in Systems Engineering" (DoD, 2011, p. 222). The ratio of (SE + PM) costs relative to total program costs offers a potentially valuable way to compare transaction costs across different programs.

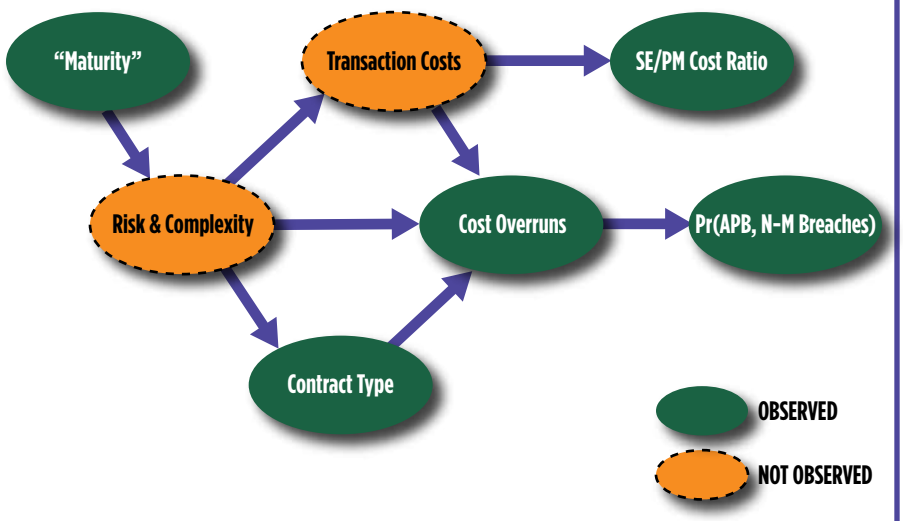
Following the method used by Biggs (2013), this study uses the SEPM cost ratio for a program as shown in Equation 1:

$$\text{SE/PM Cost Ratio} = \frac{\text{SE + PM Costs}}{\text{Total Cost}} \quad (1)$$

The numerator of the SE/PM cost ratio is the sum of SE and PM cost expenditures and the denominator is total program expenditures (estimate at completion, or EAC). A ratio is calculated to provide a perspective on the relative magnitude of SE/PM expenditures as well as to allow for comparison across different programs. The hypothesis is that programs with higher SE/PM cost ratios are more likely to experience cost breaches than programs with lower SE/PM cost ratios. This is based on the assumption that higher SE/PM cost ratios are related to riskier contractual relationships since more time, effort, and resources are expended to meet performance and schedule deadlines when compared to less risky contracts. To the extent that this is predicted early in the program, it could be useful to policy makers by providing an early warning that programs are more likely to result in cost and/or schedule overruns.

Biggs (2013) introduced the influence diagram in Figure 1, which describes the interactions between factors that may be associated with the occurrence of a cost breach. The dashed lines in Figure 1 represent factors that must be dealt with qualitatively or by using proxies. The solid lines represent factors that can be quantitatively evaluated. While the risk and complexity of a program may directly contribute to a cost overrun, the SE/PM efforts and the contract type can influence the magnitude and frequency of cost overruns as measured by cost breaches.

FIGURE 1. COST BREACH INFLUENCE DIAGRAM



Source: Biggs, 2013

Figure 1 indicates that the risk and complexity of the MDAP will guide program managers and contractors in their selection of an appropriate contract type, which in turn can influence the government's exposure to cost overruns. In all likelihood, the risk and complexity of a program will drive the level of monitoring and negotiation (transaction costs) required to manage the program, and riskier, more complex programs will require higher levels of transaction costs. Specifically, we do not expect that transaction costs themselves drive overruns, but rather that the risk and complexity that require higher levels of transaction costs drive breaches.

Cost Breaches

In this article, we will examine how the SE/PM ratio and contract type are related to the probability of incurring a cost breach. Cost breaches occur when the amount of the cost overrun exceeds certain parameters defined by regulation. Within the defense acquisition community, programs may incur two types of cost breaches: Acquisition Program Baseline (APB) and Nunn-McCurdy breaches. For a program to incur an APB breach, estimated program expenditures must be greater than the APB EAC by at least 10 percent. If the difference is 15 percent or more, a Nunn-McCurdy breach is incurred. Cost breaches frequently are incurred in six categories of appropriations: average procurement unit cost (APUC); program acquisition unit cost (PAUC); procurement; research, development, test and evaluation (RDT&E); military construction (MILCON); and acquisition-related operations and maintenance (O&M). Each of these cost breaches was included in the data set for this study.

> ***Within the defense acquisition community, programs may incur two types of cost breaches: Acquisition Program Baseline (APB) and Nunn-McCurdy breaches.***

A formal cost estimate for a program is normally developed at Milestone B, the initiation of an acquisition program, when the APB is established. The APB is used for tracking and reporting cost and schedule for the life of the program, and it includes threshold and objective values for cost, schedule, and performance. A cost threshold breach is incurred when cost expenditures exceed the cost objective by 10 percent or more (DoD, 2013). If an MDAP has been officially rebaselined,[1] cost breaches are measured to the current baseline.

Nunn-McCurdy cost threshold breaches are based on original cost estimates for PAUC and APUC at project completion. In the case of a program that has rebaselined, cost threshold breaches are also based on the current (i.e., rebaselined) cost estimate for PAUC and APUC at project completion. For purposes of this study, a cost breach is any reported in the SAR that is greater than or equal to 10 percent above the APB. The type of cost threshold breach and the APB baseline against which it is compared are shown in Table 1.

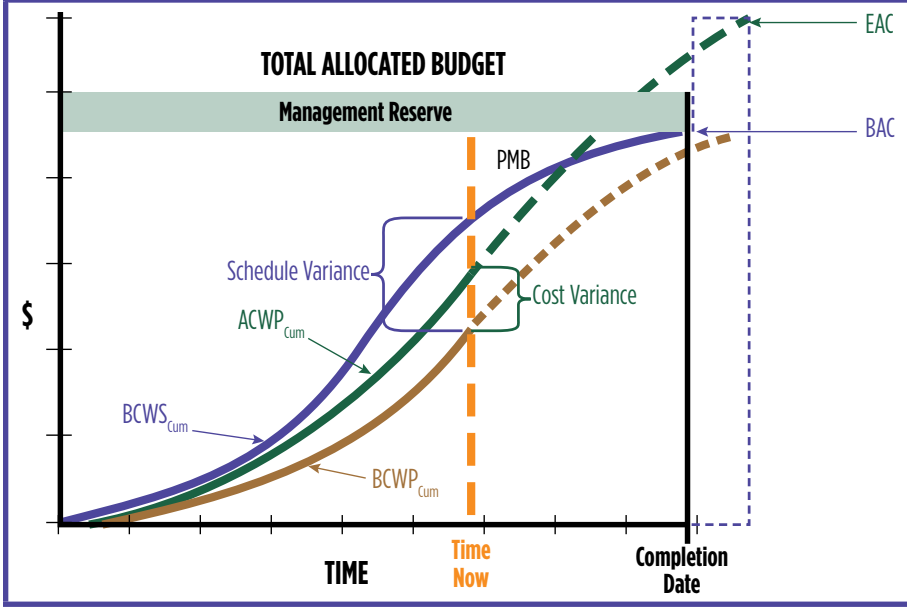
TABLE 1. APB AND NUNN-MCCURDY COST BREACH THRESHOLDS

	APB Breach (RDT&E, Procurement, MILCON, O&M)	Nunn-McCurdy "Significant" Breach (PAUC & APUC)	Nunn-McCurdy "Critical" Breach
Current Baseline Estimate	10%	+15%	+25%
Original Baseline Estimate	N/A	+30%	+50%

Source: DoD, 2013

Figure 2 can be used to illustrate cost overrun calculations. The budgeted cost of work performed (BCWP) represents the total amount budgeted for work packages that are open or completed at any given point in time. The budgeted cost of work scheduled (BCWS) represents the total amount budgeted for the work that was scheduled for completion at a given point in time. The actual cost of work performed (ACWP) is the sum of actual costs incurred to accomplish the work performed at a given point in time.

FIGURE 2. EARNED VALUE MANAGEMENT



Source: DAU Gold Card, 2015

The EAC is the sum of the ACWP and the estimate to completion (ETC) for the remaining work. The ETC can be calculated using the cost performance index (CPI) and the schedule performance index (SPI). The formula for calculating ETC is:

$$ETC = (BAC - BCWP) / (CPI * SPI) \quad (2)$$

When the EAC, a cost estimate for the total cost of the contract, is higher than the BAC, the baseline cost estimate of the contract, a cost overrun is projected. Nunn-McCurdy breaches are far rarer, perhaps because of the political threat or simply the higher threshold; thus, this article will include analysis of the potential of both types of cost overruns.

Data

This study used data originally collected by Biggs (2013) from two different data sources: SARs and the Cost and Software Data Reporting (CSDR) System. The SAR contains details of critical parameters of an MDAP, including threshold breaches, schedule, performance, current contracts, and cost details. MDAPs typically require several contracts to be executed, often concurrently. SARs provide information for the overall program and not for individual contracts. A SAR may list a single contract or many contracts for a single MDAP. Because threshold breaches are associated with contract estimates, only MDAPs that listed one contract in the "Contracts" section of the SAR were selected for purposes of this study. In addition to cost threshold breaches, the SAR indicates the time since program initiation at Milestone B, which was used in this study to indicate program maturity.

The program cost data found in the DD Form 1921 CDSR provided by the Defense Cost and Resource Center in the Defense Automated Cost Information Management System database contain significantly more contract detail than the SARs. The WBS format of the CDSR facilitates obtaining information on SE/PM costs. To simplify the data collection process, only the cost data provided by the prime contractor were recorded for further analysis. The SE/PM cost values used in this study are extracted

from the WBS line item values for "EAC SE/PM cost," which are listed on the CDSR (DD Form 1921). The EAC SE/PM cost is the projected SE/PM cost at contract completion. The SE/PM costs are inclusive of the total contract costs less the contractor's profit/loss or fees.

The SE/PM category reported by the contractor has some limitations. First, the activities included in this category will vary somewhat from contractor to contractor. As a result, a small portion of the differences in SE/PM costs between contracts may be due to differences between the accounting systems used by each contractor. The general category, however, is a reasonable measure of the cost of activities commonly associated with SE/PM. Second, the costs included in SE/PM for a single contract may vary over time as new costs are defined by the contractor as being related to SE/PM. This could explain a small portion of the increase in the SE/PM cost in some contracts, but we did not observe significant differences in our data. Finally, we recognize that the SE/PM category does not capture all possible transaction costs nor was it ever intended to. Rather, it is likely that many if not most of the activities in this category are related to transactions, as opposed to production, and thus provide a reasonable measure of transaction costs.

This article will analyze the SE/PM-to-total-cost ratios of MDAPs, looking for a potential correlation between these ratios and the probability of experiencing a cost breach. Determining the nature of any potential relationship between the SE/PM-to-cost ratio and the probability of cost breaches experienced by a program will test the hypothesis that programs with higher SE/PM cost ratios will experience cost overruns more frequently than programs with lower SE/PM cost ratios. More formally, we will test the experimental hypothesis H_1 that the probability of breach is increased by an increase in EAC SE/PM in the total cost:

$$H_1: d(\text{Probability Cost Breach}) / d(\text{EAC SEPM/Total cost}) > 0$$

$$H_0: d(\text{Probability Cost Breach}) / d(\text{EAC SEPM/Total cost}) = 0$$

The type of contract used for the program was also obtained from the CDSRs. Programs were noted as having either firm-fixed-price type contracts or cost-plus type contracts. The type of contract used for a program is an indication of the perceived level of risk associated with execution of the contract. As the level of performance risk increases, the risk of cost overruns also increases and the amount of cost risk that the contractor is willing to assume tends to decrease. Contract types differ in how the cost risk is shared between the government and the contractor. In a firm-fixed-price contract, no cost sharing exists between the government and the contractor,

and the contractor has full responsibility for the performance costs and resulting profit (or loss). In a cost-plus contract, a share ratio based on the contract cost and the contractor's fee (profit) is negotiated so that the contractor has a predetermined responsibility for the performance costs, which will directly affect the fee (profit) (U.S. General Services Administration, 2005). By including contract type in our analysis, we can account for basic risk differences recognized by both the government and the contractor at the outset of the program. Programs with aspects of both were treated as cost-plus type contracts since cost-plus contracts are a better indicator of program risk.

TABLE 2. DESCRIPTIVE STATISTICS

Variable	Obs	Mean	Std. Dev.	Min	Max
Breach—Program Av.	32	0.8125	1.090649	0	4
Nunn-McCurdy	32	0.28123	0.5226715	0	2
Program Type	32	0.516129	0.5080005	0	1
EAC SEPM from Milestone B	32	13.38844	11.58719	0.15	42.85
EAC SEPM Program Average	32	14.66727	10.68449	0.87	43.31
To Date SEPM Program Average	30	16.59583	13.81136	1.4	54.66667

Table 2 describes the data used in our study. The study covers 32 programs over 84 program years. Despite not having greatly disparate thresholds, our sample reflected far more APB breaches—26 program years—versus only 9 program years for Nunn-McCurdy breaches. Approximately half of the programs were firm-fixed-price and half were cost-plus type contracts. We also compared three different measures of the SE/PM ratio. The first measure is for the EAC of the SE/PM ratio to total costs, as estimated at Milestone B. SE/PM are on average about 13 percent of total costs estimated at Milestone B. Programs that rebaseline would update this measure, but for purposes of this study we maintain the original prebreach measure because we are interested in the predictability of breaches based on original assessments of risk. The second measure is still the EAC, but programs update this measure

as they go along. This number is about 1.5 percentage points higher than the Milestone B estimate or 14.7 percent of total costs. We also include the actual to date SE/PM to total cost at each point in time for our sample. At 16.6 percent of total costs, this is even higher than either predicted share, indicating that estimates are on average overoptimistic and that SE/PM costs grow, on average, faster than total costs.

Analysis of the data shows that more than half of the MDAPs in the study initially estimated an EAC SE/PM cost ratio of 0.10 or less and experienced fewer than two cost breaches since 1998. Furthermore, it can be inferred that most of the programs have experienced at least one cost breach, which seems to confirm a RAND report finding that most MDAPs' actual costs exceeded baseline cost estimates (Arena, Leonard, Murray, & Younossi, 2006).[2] Observations of the MDAP SE/PM-to-total-cost ratios agree with the RAND study, suggesting that trends in SE/PM costs vary across MDAPs (Stem et al., 2006). Recall that SE/PM costs are used as proxy measures of the transaction costs required to administer and manage the MDAP.

Methodology

Because our data set includes programs that have not experienced cost breaches over the time period studied, our data are considered to be "right censored." This means that ordinary linear regression is not a good option for analyzing the data. Instead, we employ survival analysis to test whether relatively high Milestone B EAC SE/PM is a predictor of cost breaches. Survival analysis is typically used in medicine and social sciences to examine when an event of interest will occur. For example, in medicine where the event of interest is a heart attack, we can use survival analysis to predict whether a patient will suffer a heart attack within a period of time. In this study, the event of interest is a cost breach, and we are interested in whether a program will experience a cost breach.

In our medical example, we could use survival analysis to identify risk factors, such as obesity, that might indicate a greater propensity for suffering a heart attack. In this study, we are looking for risk factors that might predict cost breaches. Two explanatory variables were included in the analysis: EAC SE/PM cost ratio and program contract type (fixed-price or cost-plus). While the exact nature of the relationship between cost threshold breaches and these explanatory variables is unknown, it is reasonable to presuppose that the explanatory variables influence the cost performance of the MDAPs as shown in Figure 1.

Using survival analysis, we construct a hazard function for cost breaches. A hazard function shows (over time) the probability that an event (such as a cost breach) will be incurred. As programs can experience multiple cost breaches despite rebaselining, we allow for multiple breaches over time[3] and estimate how the hazard of cost breach varies with our explanatory variables. Hazard models are also useful because they are more tolerant of gaps and censoring. Hazard models can be thought of as conditional logits (Cleves et al., 2010). We allow for repeat failures over the period—that is, following cost breaches, we allow a program to stay in the sample.

Survival analysis uses time-at-risk as its relevant time metric. Thus, we measure "survival time" in terms of the maturity of the design and technology of the system. In this study, program maturity is measured by the time elapsed since Milestone B, the entry point into the Engineering and Manufacturing Development phase. For a program to receive approval to begin Milestone B in DoD, the design and technology associated with the system must be considered "mature."[4]

In this analysis, we use the Cox-Relative Hazard. It is considered semiparametric because it does not imply a specific functional form on the hazard of breaches over time. The proportional hazard model is specified as:

$$h_j(t) = h_0(t) \exp(x_j \beta_x)$$

which states that the hazard a particular subject j faces at time t is a function of the baseline hazard modified proportionally by the vector of regression coefficients β_x. The Cox model does not estimate the baseline hazard. We can convert coefficients from these regressions to cumulative hazard ratios to understand the marginal effect on the baseline hazard of a change in the coefficient. This is done simply by calculating the exponent of the coefficient and using it as a multiplier (e.g., the value 0.9 would correspond with a 10 percent reduction, and 1.1 would be a 10 percent increase). While we report coefficients, we interpret our results using exponentiated hazard ratios—that is, the cumulative hazard of a cost breach.

We next examine whether baseline SE/PM-to-cost ratios influence the probability of a Nunn-McCurdy breach using a similar analysis. While the difference between the two is mainly the 10 percent versus 15 percent threshold, Nunn-McCurdy breaches are sufficiently rare that they may have significantly different causes.

Finally, we test the robustness of our finding using logit models. Logit is commonly used to determine the influence of exogenous variables on the probability of a dichotomous outcome, such as whether or not a cost breach occurs in any given program year. Logit is preferred over a linear regression model because, using a logistic function, it constrains all probability-of-occurrence estimates to be between 0 and 1. Formally, the logit model for the probability can be written as:

$$P(\text{Breach}) = \frac{e^{x\beta}}{1 + e^{x\beta}}$$

Where $x\beta$ is a function of the vector of explanatory variables.

We are curious as to whether Milestone B SE/PM predictions are the best predictors of breaches or whether within-program changes in SE/PM estimates or actuals should cause concern about program health. To test, we use a simple logit model, which predicts the probability of failure on the baseline EAC SE/PM ratios as in our hazard model. We cluster the standard errors by program. We use a fixed effects (conditional) logit to model whether a change in either EAC or the actual SE/PM cost ratio for an MDAP will change its probability of breaching a cost threshold. Formally, this model measures the impact of deviations by the independent variable from the program's mean (Allison, 2001).

Results

We find that higher estimated SE/PM ratios are associated with a higher risk of APB breaches. Figures 3 and 4 show the cumulative risk of APB and Nunn-McCurdy breaches over program maturity. Table 3 shows the results for Hazard models for APB breaches, and Table 4 shows the results for Nunn-McCurdy breaches

FIGURE 3. HAZARD OF COST BREACH

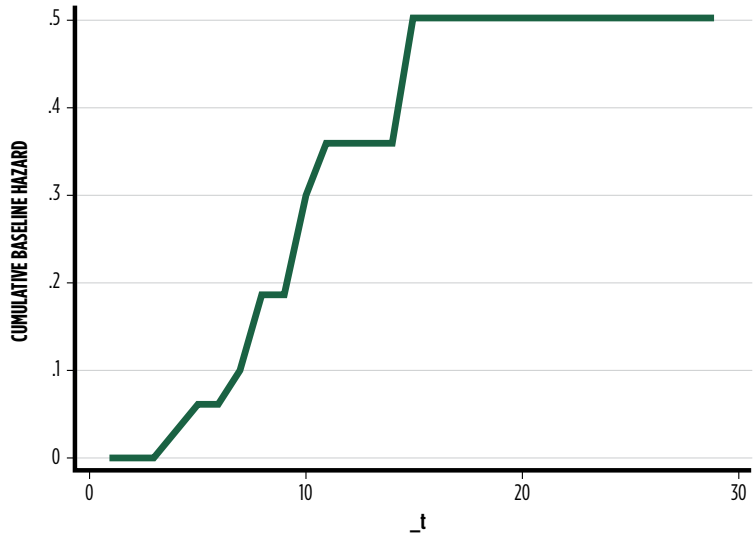


FIGURE 4. HAZARD OF NUNN-MCCURDY BREACH

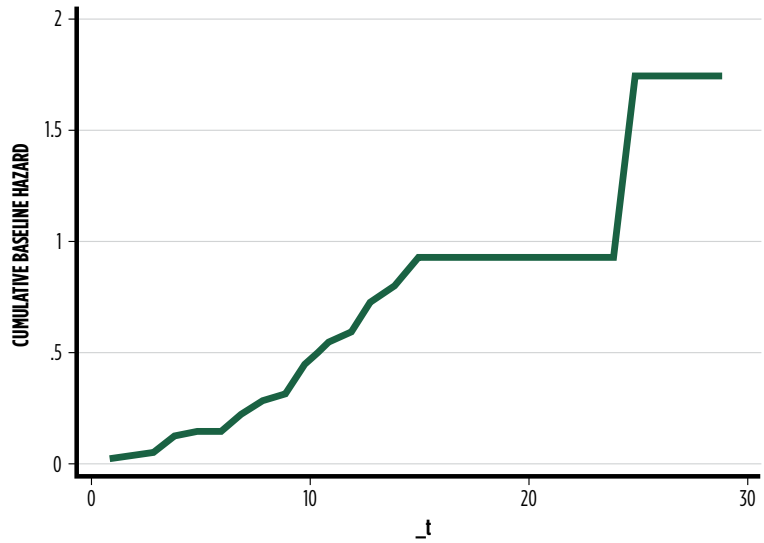


TABLE 3. APB BREACH HAZARD		
Variables	**(1)**	**(2)**
EAC SE/PM from	0.0482***	0.0284*
Milestone B	(0.0147)	(0.0168)
Type		1.125**
		(0.552)
Observations	84	84

Note. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

In the first model a 1 percentage point increase in the estimated SE/PM ratio at completion increases the risk of breach by 5 percent, a result that is statistically significant at the 1 percent level. When contract type is added as a control, the impact of the SE/PM ratio goes down to 3 percent and its significance is reduced to the 10 percent level. Looking at the impact of contract type, we find that having a cost-plus type contract multiplies the risk of an APB breach by 3.1, which is significant at the 5 percent level.

TABLE 4. NUNN-MCCURDY BREACH HAZARD		
Variables	**(3)**	**(4)**
EAC SE/PM from	0.0247	0.00352
Milestone B	(0.0268)	(0.0290)
Type		1.269
		(0.886)
Observations	84	84

Note. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Nunn-McCurdy breaches are significantly less common than APB breaches and SE/PM ratios or contract type do not appear to determine them. The SE/PM ratio is not a significant predictor of Nunn-McCurdy breaches, and while type has a similar magnitude to its impact on APB breaches, it is not statistically significant either.

TABLE 5. LOGIT ANALYSIS

Variables	(1) Logit	(2) Fixed Effects	(3) Fixed Effects
Baseline EAC SE/PM	0.0433* (0.0244)		
To Date SE/PM		-0.0358 (0.0491)	
EAC SE/PM			-0.0924 (0.0782)
Constant	-1.433*** (0.508)		
Observations	84	36	39
Number of programs		10	11

Table 5 shows the results of logit analysis for APB breaches. We find that the likelihood of a cost breach is related to the EAC SE/PM ratio predicted at milestone B, but not to changes in the predicted ratio or to the actual SE/PM ratio. The marginal effect of the logit model is very similar to the hazard function and statistically significant at the 10 percent level: for every 1 percent increase or decrease in the EAC SE/PM cost ratio, there is an increase or decrease of 4 percent in the probability of a program sustaining a cost threshold breach. We do not find any within-program impact using fixed effects logit models, indicating that a change in the EAC SE/PM ratio is not an indicator of a potential breach. Thus forecasts of cost breaches should focus on initial SE/PM ratio estimates.

Conclusion

This article successfully tested the hypothesis that transaction costs could help explain future cost breaches of MDAPs. Using SE/PM costs as a ratio of total program costs, we find the greater this ratio is at the outset (Milestone B estimate), the greater the risk of eventual cost breaches. This information reflects the program manager's implicit assessment of the risk of a program and can be a valuable early indicator of which programs will benefit from greater oversight. We should be careful to note that high SE/PM ratios may be the result of program managers responding proactively to program risks. As such, we are not suggesting that high SE/PM ratios are a bad thing—simply that they can be used to predict cost breaches, which often occur in high-risk, more complex programs. This suggests that the SE/PM ratio is a measurable indicator of cost risk and anticipated transaction costs.

This article also offers an innovative way of looking at cost breaches, using survival analysis to forecast cost breaches in MDAPs over a program's life cycle. We offer somewhat robust analysis, using a more traditional logit analysis, of our predictions. We believe this is a step forward in using measures available in DoD's vast databases of cost information to develop more robust forecasts of potential cost overrun risks in programs. These findings suggest that the department could benefit from capturing more explicit measures of transaction costs to determine more precisely their role in predicting cost variability.

Appendix

PROGRAMS SELECTED FOR STUDY

Active Electronically Scanned Array (AESA) Radar
AIM-9X/Short Range Air-to-Air Missile
AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM)
Airborne and Maritime/Fixed Station Joint Tactical Radio System (AMF JTRS)
AN/WQR-3, Advanced Deployable System (ADS)
Apache Block IIIA Remanufacture (AB3A REMANUFACTURE)
AV-8B/Attack, V/STOL, Close Air Support (Harrier II+ Remanufacture)
B-2 Radar Modernization Program
Cobra Judy Replacement (Cobra Judy Replacement)
EA-18G Growler (EA-18G)
Expeditionary Fighting Vehicle (EFV)
E-3 AWACS Radar System Improvement Program (RSIP)
E-2C Reproduction
Family of Advanced Beyond Line-of-Sight Terminals (FAB-T)
Family of Medium Tactical Vehicles (FMTV)
Guided Multiple Launch Rocket System/DPICM/Unitary/Alternative Warhead (GMLRS/GMLRS AW)
Joint Common Missile (JCM)
Joint Tactical Radio System Ground Mobile Radio (formerly Cluster 1) (JTRS GMR)
Longbow Hellfire - subsystem of the AH-64 Apache Weapon System
LHA Replacement Amphibious Assault Ship
MQ-4C Unmanned Aircraft System Broad Area Maritime Surveillance (MQ-4C UAS BAMS)
Multi-Platform Radar Technology Insertion Program (MP-RTIP)
National Polar-orbiting Operational Environmental Satellite System (NPOESS)
Presidential Helicopter Replacement (VH-71) Program
P-8A Poseidon
Sense and Destroy Armor (SADARM)
Small Diameter Bomb Increment II (SDB II)
Space Based Infrared System (SBIRS) High Program
Standard Missile (SM) - 2 Block IV
Stryker Family of Vehicles (STRYKER)
UH-72A Light Utility Helicopter (LUH)
Warfighter Information Network - Tactical (WIN-T)

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Endnotes

[1] Circumstances authorizing changes to the baseline are limited; revisions to the current APB are not authorized unless there is a significant change in program parameters and must be approved by the Milestone Decision Authority (DoD, 2013).
[2] For most of the programs reviewed, actual costs exceeded the baseline cost estimate established at Milestone B (program initiation), as measured by the cost growth factor (Arena et al., 2006).
[3] For robustness, we also ran the analysis without allowing for multiple breaches, and while the results were weaker, they were still statistically significant and of a similar magnitude. Still, the fact that including multiple breaches strengthens our results, indicates that programs with high levels of complexity and risk often suffer for these high levels repeatedly.
[4] Milestone B approval authorizes an MDAP to enter the Engineering and Manufacturing Development phase of the acquisition process. Statutory requirements for MDAPs to achieve Milestone B approval are found in Title 10 U.S.C. § 2366b. These requirements stipulate that the program be certified by the Milestone Decision Authority to be affordable, fully funded through the Future Years Defense Program (FYDP), and that the cost and schedule estimates are reasonable.

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